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GB 1536947
GB 1531950
GB 1500102
GB 1448743
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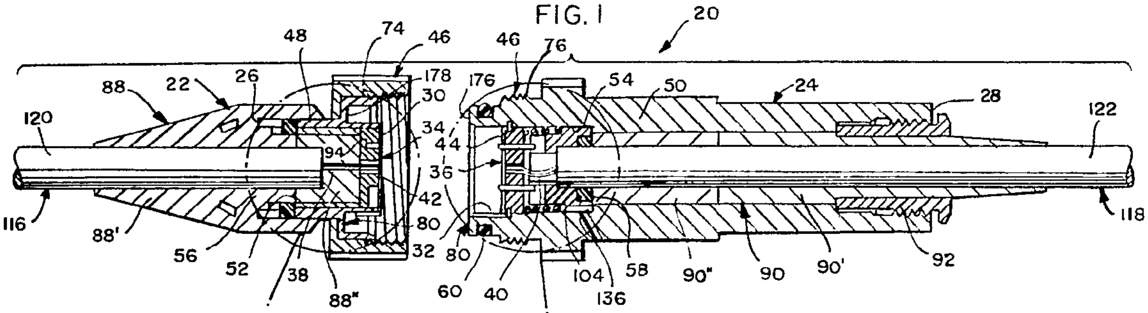
(71) (72) and (74) continued overleaf

(54) **Fiber optic connector for high density applications and method of manufacturing fiber optic connectors**

(57) The present invention relates to fiber optic connectors and, more particularly, to a fiber optic connector for optically interconnecting two high density sets of optical fibers and a method of manufacturing fiber optic connectors. While prior art fiber optic connectors are available, they are generally limited to connectors for a small number of communication channels. Recently, there has been a growing interest in and recognition of the need for, developing a suitable fiber optic connector for optically interconnecting two high density sets of optical fibers, particularly for single fiber cables, with low loss and minimum cross-talk characteristics. The connector of this invention satisfied this need. The connector includes a pair of connector members 22, 24 each having a rear end and a forward, mating end 30, 32. It also includes means 34, 36 associated with the forward, mating end of each of the connector members for terminating one high density set of optical fibers 38, 40, each of the terminating members including means for disposing the optical fibers of one high density set in a predetermined pattern. The connector further includes means 74, 76 for securing the connector members together with the forward, mating ends thereof adjacent. With these features of construction, the connector is well suited for optically aligning two high density sets of optical fibers.

FIG. 1



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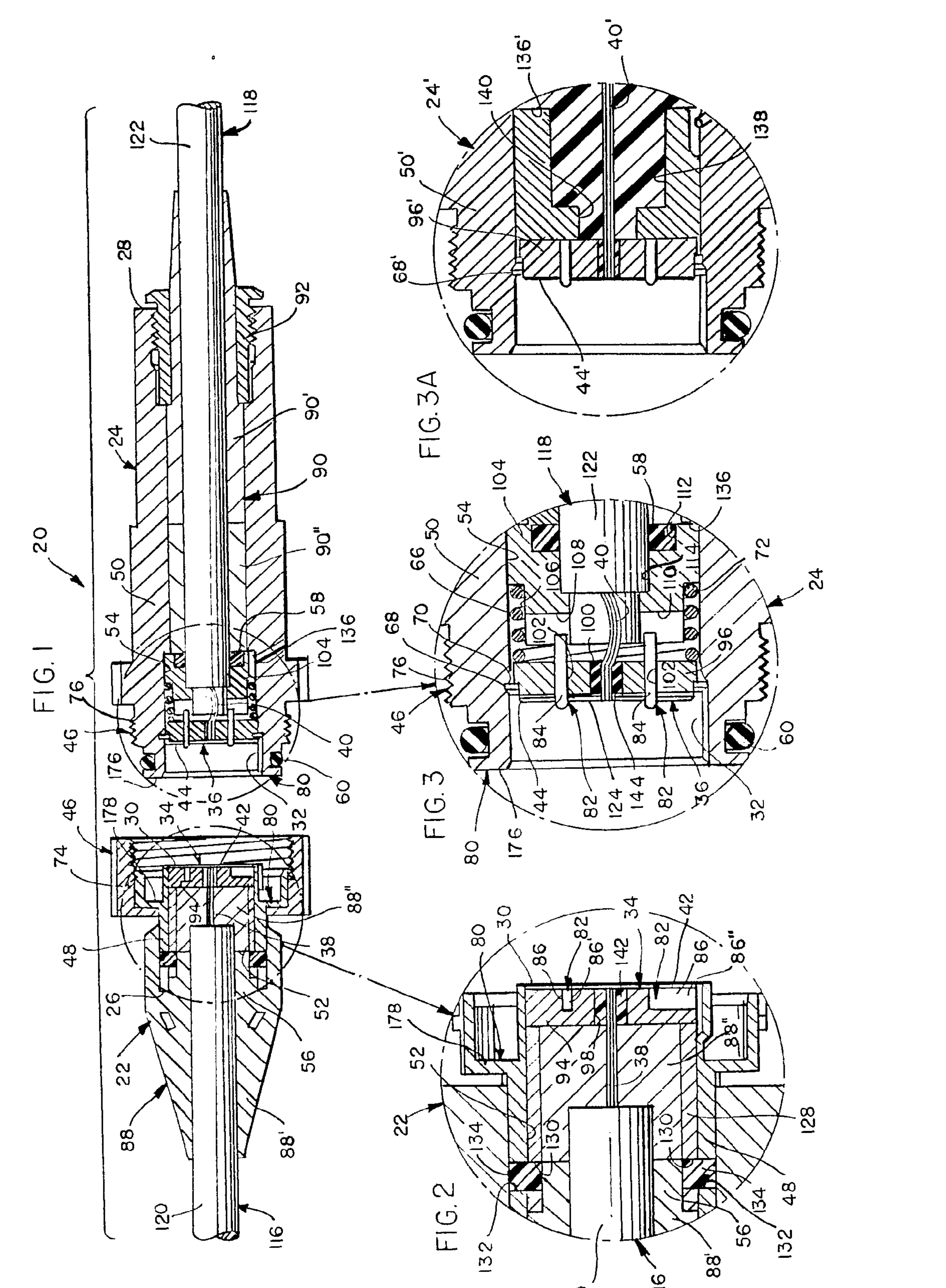


FIG. 1

FIG. 2

FIG. 3

FIG. 3A

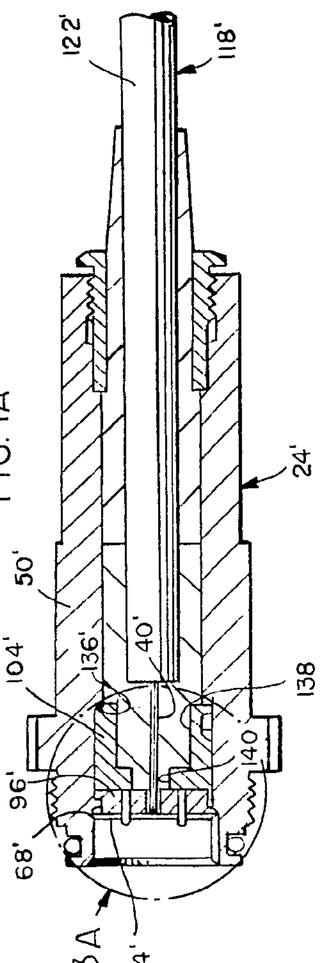


FIG. 1A

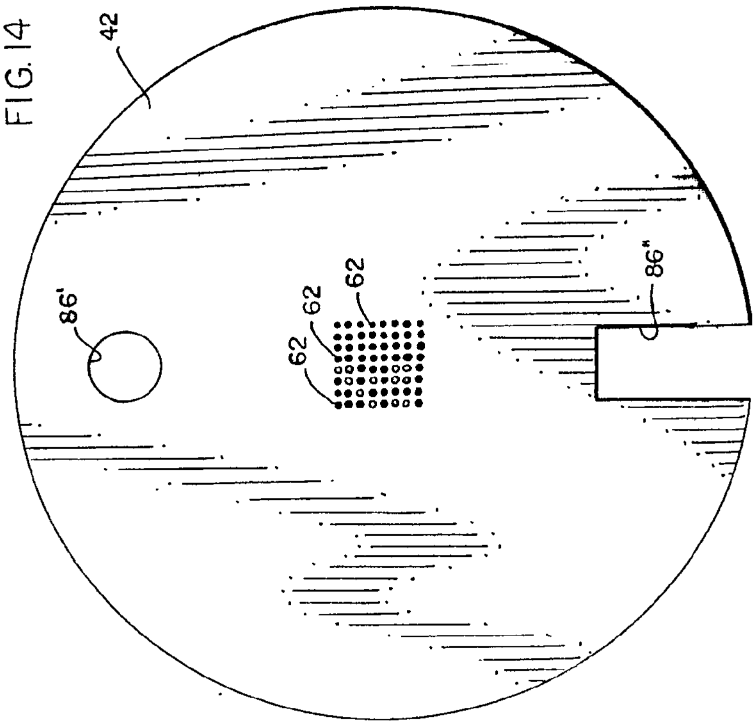


FIG. 14

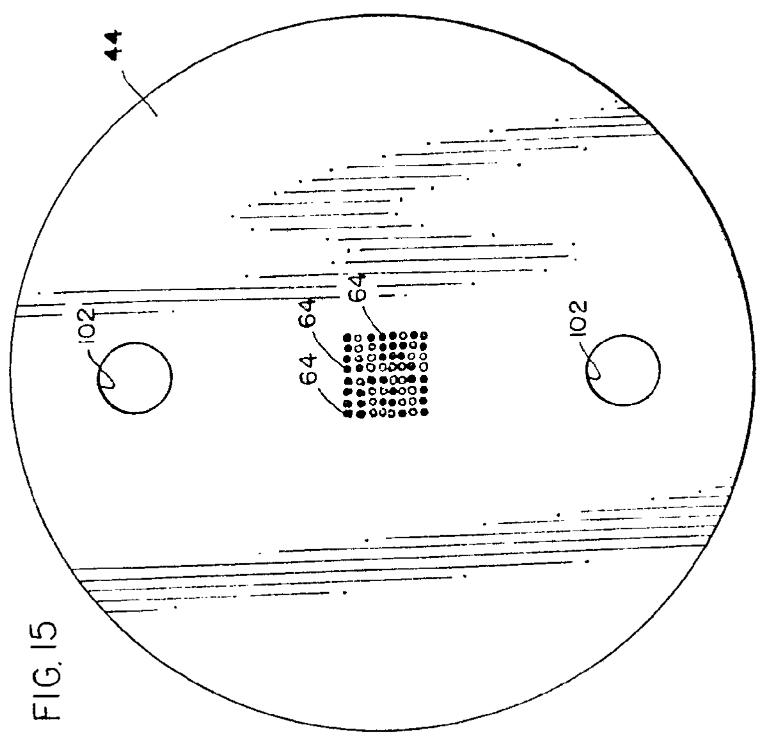


FIG. 15

FIG. 5

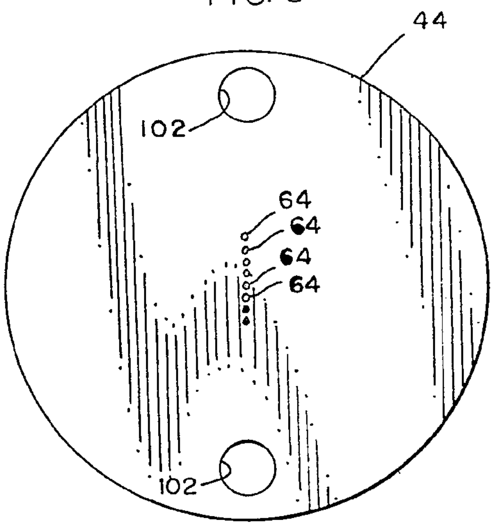


FIG. 4

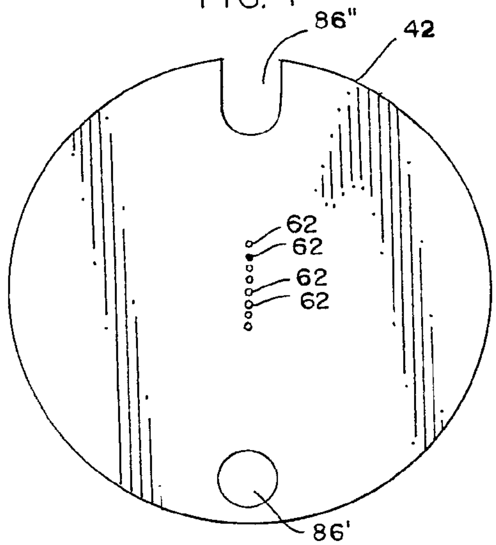


FIG. 6

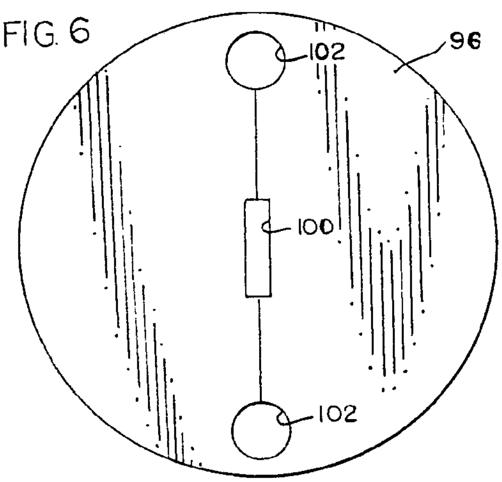


FIG. 7

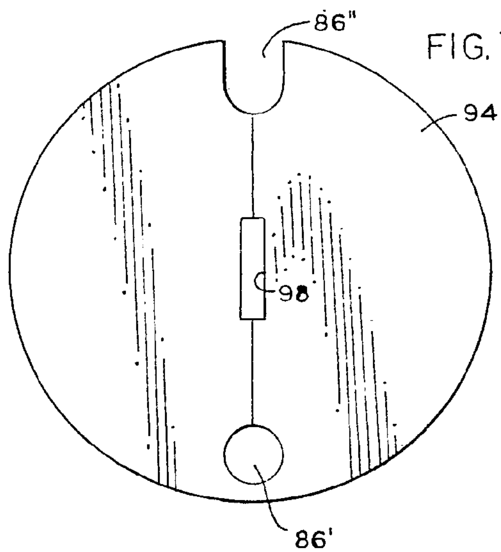


FIG. 8

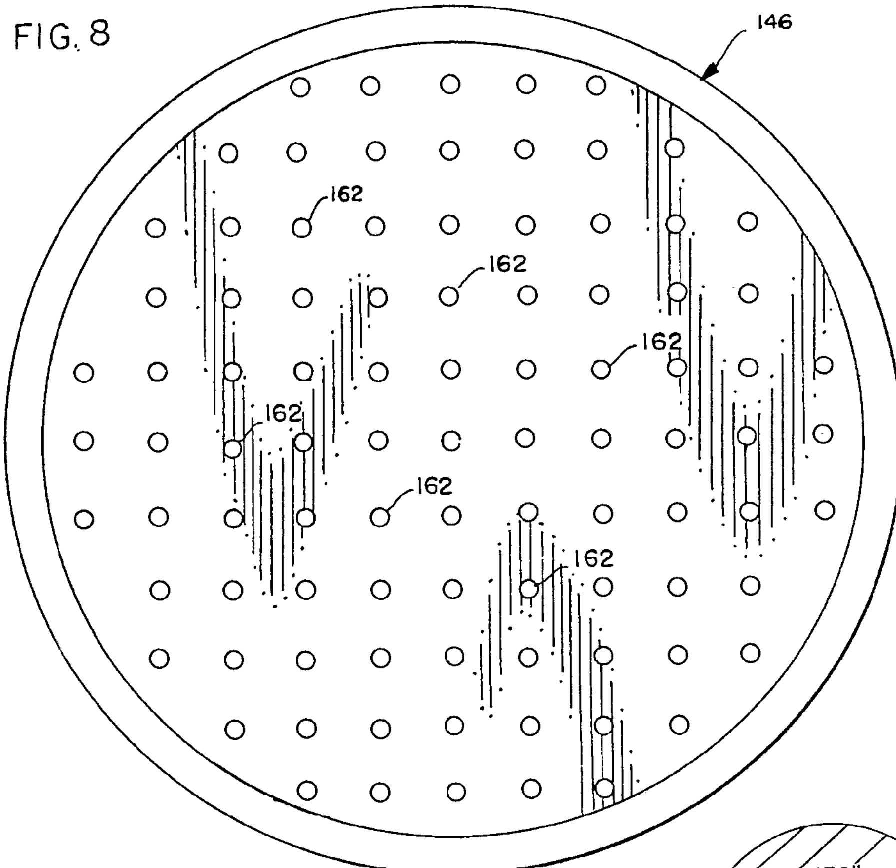


FIG. 9

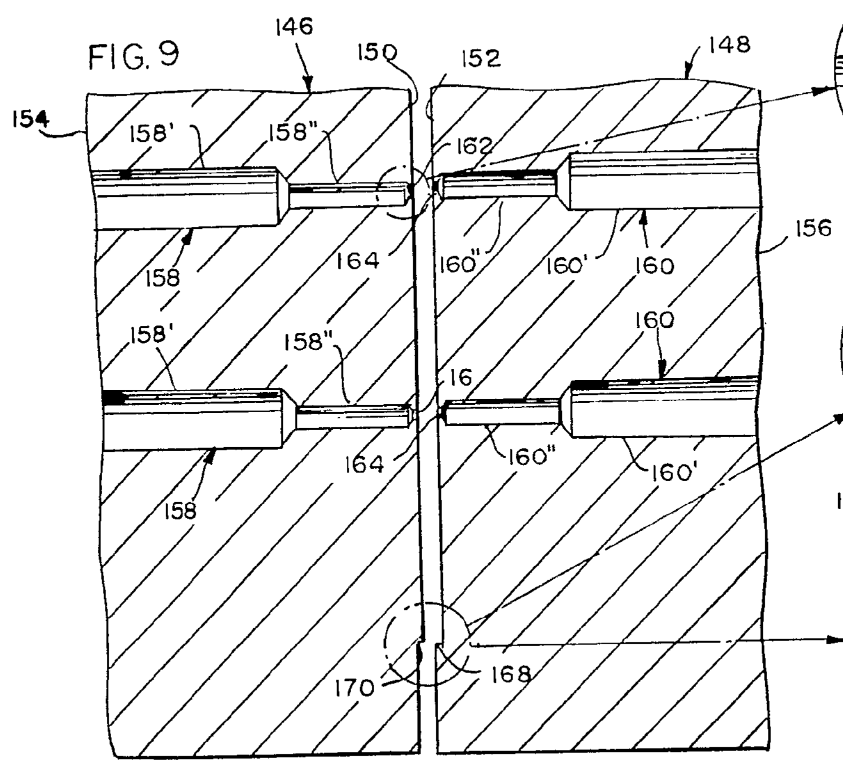


FIG. 10

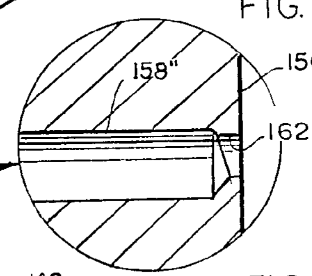


FIG. 11

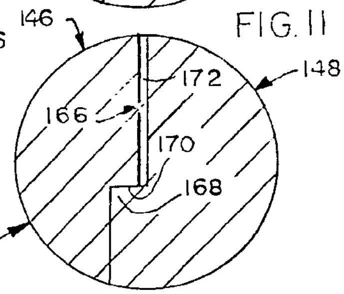
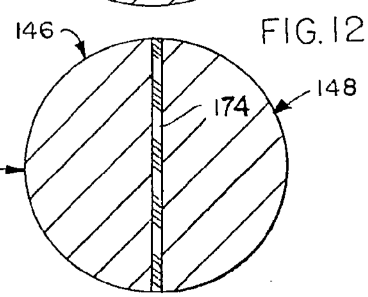


FIG. 12



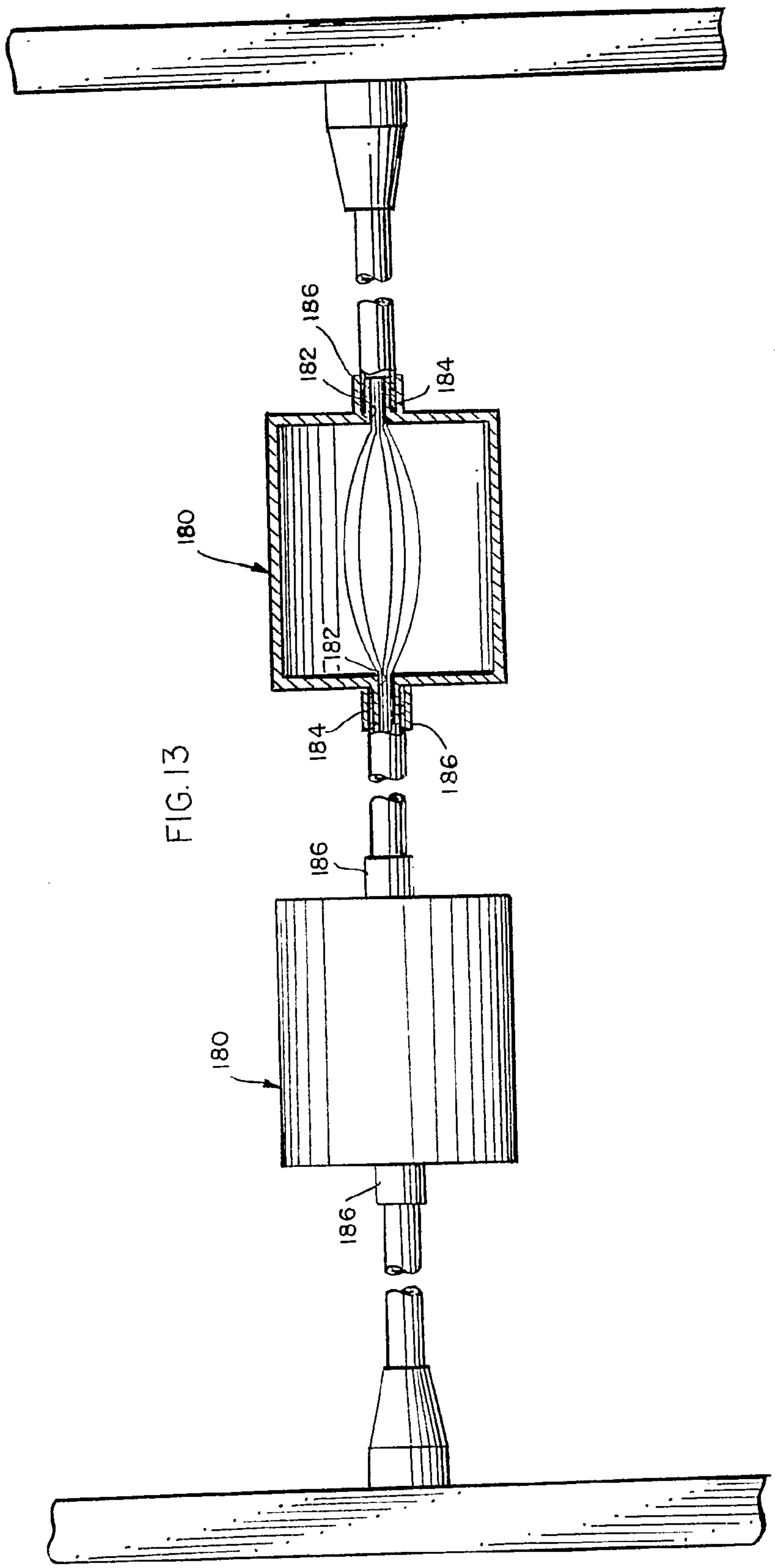


FIG. 13

SPECIFICATION

Fiber optic connector for high density applications and method of manufacturing fiber optic connectors

TECHNICAL FIELD

The present invention relates to fiber optic connectors and, more particularly, to a fiber optic connector for optically interconnecting two high density sets of optical fibers and a method of manufacturing fiber optic connectors.

BACKGROUND OF THE PRIOR ART

In recent years, fiber optic communication lines made up of parallel optically-conductive fibers arranged to form a flexible cable for conveying light from one location to another have come into increasing use. The applications have varied, although one particularly significant application has been conveying data from one location to another by modulating a light source with data to be transmitted at one end of the cable and recovering the data at the other end of the cable with a photo sensitive detector. Since the data is conveyed by a medium not subject to radio frequency interference or detection, fiber optic communication lines are particularly well adapted for applications requiring a high degree of security like those found in the data processing field.

With the increasing use of fiber optic communication lines, the need has developed for connectors capable of joining segments of cables with minimum detriment to the optical transmission path. It has been found that precise axial and angular alignment between a pair of fiber optic cables can be achieved by terminating the optical fibers of the cables in connector pin assemblies in such a way that the optical fibers are concentrically aligned with respect to the outer dimension of the connector pins. When a pair of connector pins are concentrically aligned, the ultimate result is that the optical fibers will likewise be angularly and axially aligned for efficient light transfer.

While the connector art has been developing, the primary focus has been upon connectors for a small number of channels. More recently, there has been a growing interest in and recognition of the need for, developing a suitable fiber optic connector for optically interconnecting two high density sets of optical fibers, particularly for single fiber cables. Understandably, this interest has developed out of an appreciation for the fact that the extremely high capacities associated with fiber optic cables can be expanded dramatically by using high density sets or arrays of optical fibers. More particularly, there has been an increasing awareness of the desirability of developing a fiber optic connector that will expand capacity by several orders of magnitude. Additionally, fiber optic connectors should exhibit low loss and minimum crosstalk characteristics.

Although the advantages of a fiber optic connector for high density applications have been appreciated, the desirability and need has remained for a practical embodiment. It has not previously been known or suggested how to achieve the goal of a fiber optic connector for optically interconnecting two high density sets of optical fibers with low loss and crosstalk characteristics. Accordingly, a practical fiber optic connector for high density applications has never before been available even though desirability and need therefor have long been known and appreciated.

BRIEF SUMMARY OF THE INVENTION

Accordingly, the present invention, in its broadest sense, is directed to a fiber optic connector for high density applications and a method of manufacturing such a fiber optic connector. The connector includes a pair of connector members each having a rear end and a forward, mating end. It also includes means associated with the forward, mating end of each of the connector members for terminating one high density set of optical fibers, each of the terminating members including means for disposing the optical fibers of one high density set in a predetermined pattern. The connector further includes means for securing the connector members together with the forward, mating ends thereof adjacent. With these features of construction, the connector is well suited for optically aligning two high density sets of optical fibers.

More specifically, the connector members preferably each include a connector shell having an opening sized and shaped to accommodate one high density set of optical fibers extending completely therethrough from the rear end to the forward, mating end. The connector shells may each include means integral therewith for providing a sealed connector. The sealing means suitably includes means associated with the rear ends and means associated with the forward, mating ends when the connector members are secured together. The terminating means may each include surface means for disposing the optical fibers of one high density set in a predetermined pattern. The surface means suitably disposes the optical fibers of the two high density sets in parallel planes. moreover, the surface means preferably each include an alignment member having optical fiber receiving holes therein defining the predetermined pattern and being at least sufficient in number to receive the optical fibers of one high density set.

In one embodiment, the connector preferably includes means associated with at least one of the connector members for biasing the

terminating means of the connector member forwardly therein. The connector member then suitably includes stop means to limit forward movement of the terminating means caused by the biasing means. The biasing means is preferably a spring and the stop means a retaining ring with the connector member including a ring receiving groove for the retaining ring forwardly of the terminating means and a spring supporting surface for the spring rearwardly of the terminating means. The securing means suitably includes a first coupling member associated with one of the connector members and a second coupling member associated with the other of the connector members. The first coupling member is engageable with the second coupling member to secure the connector shells together. Additionally, the securing means optionally includes means for limiting engagement of the first coupling member with the second coupling member to control separation of the optical fibers of the two high density sets.

Additionall features of this embodiment include means for orienting the pair of connector members such that the optical fibers of the two high density sets are in optical alignment when the connector members are secured together with the forward, mating ends thereof adjacent. Also, the orienting means may include at least two pins associated with the terminating means of one of the connector members and a corresponding number of pin receiving openings associated with the terminating means of the other of the connector members.

In another embodiment, the fiber optic connector is also well suited for optically interconnecting two high density sets of optical fibers. The connector includes a pair of connector shells each having a rear end and a forward, mating end and having an opening extending completely therethrough from the rear end of the forward, mating end with the opening in each of the connector shells being sized and shaped to accommodate one high density set of the optical fibers. It also includes means associated with the forward mating end of each of the connector shells for terminating one high density set of the optical fibers with each of the terminating means including surface means for disposing the optical fibers of one high density set in a predetermined pattern defined by optical fiber receiving holes in the surface means at least sufficient in number to receive the optical fibers of one high density set. The connector also includes means associated with each of the connector shells rearwardly of the surface means for providing stress relief for the optical fibers of one high desnity set and means for securing the connector shells together with the forward, mating ends thereof adjacent. With these features of construction, the fiber optic connector similarly optically aligns the two high density sets of optical fibers.

Additional features of this embodiment include the connector shells each having means associated therewith for providing a sealed connector. The sealing means preferably includes means associated with the rear ends and means associated with the forward, mating ends when the connector members are secured together preferably in the form of a resilient O-ring disposed in a circumferentially extending groove in one of the connector shells. The terminating means preferably each include an alignment plate comprising the surface means and a backplate disposed rearwardly of the alignment plate to provide support therefor. In addition, the alignment plates are preferably secured to the backplates.

More particularly, the backplates preferably each include an enlarged bore at least coextensive with the corresponding ones of the optical fiber receiving holes. The optical fibers of one high density set then pass through the enlarged bores of each of the backplates to the corresponding one of the alignment plates where they are secured. The terminating means suitably includes means for orienting the pair of connector shells such that the optical fibers of the two high density sets are in optical alignment when the connector shells are secured together with the forward, mating ends thereof adjacent with the orienting means including at least two pins associated with the terminating means of one of the connector shells and a corresponding number of pin receiving openings associated with the terminating means of the other of the connector shells. The pins are preferably secured in pin receiving bores in the alignment plate and backplate of one of the connector shells and the alignment plate and backplate of the other of the connector shells includes a corresponding number of pin receiving openings. In one embodiment, the pin receiving openings include an alignment hole and an alignment slot with the alignment hole and the alignment slot being adapted to receive the pins for oriented and aligned interengagement of the connector shells.

Other details of this embodiment may include a rigid insert in at least one connector shell secured therein against rearward movement with a circumferential groove defining a spring supporting surface. The spring supporting surface is provided to support a spring disposed between the rigid insert and the backplate and biasing the backplate forwardly within the connector shell against a retaining ring disposed in a ring receiving groove in the connector shell. It will be appreciated that the rigid insert is therefore preferably spaced rearwardly of the backplate and, also, the optical fibers are preferably free to flex in the region between the backplate and the rigid insert. The backplate and alignment plate preferably include a pair of pins cooperating with a pair

of slots in the rigid insert to key the terminating means to the connector shell in a manner permitting relative axial movement. Addionally, the connector preferably includes spacer means in the form of a planar sheet having an opening therethrough at least coextensive with the optical fiber receiving holes which cooperates with the spring to permit controlled separation of the two high density sets of optical fibers, the terminating means being located so as to be in contact with the spacer means when the connector shells are secured together.

Other advantageous features may include a backplate support member disposed and secured rearwardly of the backplate in each of the connector shells. The terminating means may each include a block having a front face defining the surface means and a rear face with the bores extending substantially through the blocks from the rear face toward the front face and with the blocks also each having precision formed optical fiber receiving holes in the front face in communication with the bores. The connector may also include means for orienting the connector shells in the form of a lip on one of the terminating means and a lip receiving groove on the other of the terminating means such that the optical fibers of the two high density sets are in optical alignment when the lip is disposed in the lip receiving groove. The stress relief means may include a potting compound associated with each of the connector shells with an elastic compound preferably being located adjacent the rear ends thereof and a rigid resin being located forward of the elastic compound. The securing means may include an internally threaded coupling ring associated with one of the connector shells and an externally threaded surface associated with the outer of the connector shells together with optional means for limiting threading engagement of the internally threaded coupling ring in the externally threaded surface to control separation of the optical fibers of the two high density sets. Finally, the predetermined pattern may be defined by at least one row of optical fiber receiving holes, and preferably a plurality of rows and columns of optical fiber receiving holes, the surface means each including a perforated metal alignment plate having the rows and columns of optical fiber receiving holes therein.

In the method of manufacturing a fiber optic connector for optically interconnecting two high density sets of optical fibers, the steps are the following. First, a pair of connector members each having a rear end and a forward, mating end are provided. Second, a terminating member for association with the forward, mating end of each of the connector members is provided. Third, optical fiber receiving holes are placed in each of the terminating members in a predetermined pattern. Fourth, one of the terminating members is secured in the forward, mating end of each of the connector members. Fifth, the optical fibers of one high density set are secured in the optical fiber receiving holes in each of the terminating members. Preferably, the terminating members are metal and the optical fiber receiving holes are placed by means of metal etching.

The present invention is therefore directed in its broadest sense to a fiber optic connector for high density applications and a method of manufacturing fiber optic connectors. It includes features of construction well suited for optically interconnecting two high density sets of optical fibers using a surprisingly advantageous combination and arrangement of components which make it possible to increase the capacity of prior fiber optic connectors by several orders of magnitude. Other objects and advantages of the present invention will be appreciated from a consideration of the details of construction and operation set forth in the accompanying specification, claims and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The invention, together with the further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings. In the drawings, like reference numerals identify like elements in the several figures in which:

Figure 1 is a cross-sectional view illustrating a fiber optic connector for optically interconnecting two high density sets of optical fibers in accordance with the present invention;

Figure 1A is a cross-sectional view illustrating an alternative embodiment for a connector member constructed in accordance with the present invention;

Figure 2 is an enlarged detailed view of a portion of one of the connector members illustrated in Fig. 1;

Figure 3 is an enlarged detailed view of a portion of the other connector member illustrated in Fig. 1;

Figure 3A is an enlarged detailed view of a portion of the connector member illustrated in Fig. 1A;

Figure 4 is a front plate elevational view of one form of alignment plate;

Figure 5 is a front elevational view of another form of alignment plate;

Figure 6 is a front elevational view of one form of backplate;

Figure 7 is a front elevational view of another form of backplate;

Figure 8 is a front elevational view of an alternative embodiment of terminating means;

Figure 9 is a cross-sectional view of an

alternative embodiment of terminating means;

Figure 10 is an enlarged detailed view of a portion of the terminating means illustrated in Fig. 9;

Figure 11 is an enlarged detailed view of a portion of the terminating means illustrated in Fig. 9;

Figure 12 is an enlarged detailed view of an alternative embodiment for controlling separation of terminating means;

Figure 13 is a front elevational view, partially in section, illustrating splice boxes and fusion splicing useful with fiber optic connectors for optically interconnecting two high density sets of optical fibers in accordance with the present invention;

Figure 14 is a front elevational view of an alignment plate useful with a high density array of optical fibers; and

Figure 15 is a front elevational view of another alignment plate useful with a high density array of optical fibers.

DETAILED DESCRIPTION OF THE INVENTION

With reference first to Fig. 1, the numeral 20 designates generally a fiber optic connector for optically interconnecting two high density sets of optical fibers in accordance with present invention. The connector 20 includes a pair of connector members 22 and 24 having rear ends 26 and 28 and forward, mating ends 30 and 32. It also includes means 34 and 36, respectively, associated with the forward, mating ends 30 and 32 of the connector members 22 and 24 for terminating one high density set of optical fibers (such) as 38 and 40, respectively) with the terminating means 34 and 36 including means 42 and 44 for disposing the optical fibers of one high density set (such as 38 and 40) in a predetermined pattern. The connector 20 further includes means 46 for securing the connector members 22 and 24 together with the forward, mating ends 30 and 32 thereof adjacent. With these features of construction, the connector 20 optically aligns the two high density sets 38 and 40 of optical fibers.

Referring to Figs. 2 and 3, the connector members 22 and 24 include connector shells 48 and 50 having openings 52 and 54 sized and shaped to accommodate one high density set of the optical fibers extending completely therethrough from the rear ends 26 and 28 to the forward, mating ends 30 and 32. The connector shells 48 and 50 each include means integral therewith for providing a sealed connector including means 56 and 58 associated rearwardly of the forward, mating ends 30 and 32 and means 60 associated with the forward, mating ends 30 and 32 when the connector members 22 and 24 are secured together. The terminating means 34 and 36 each include surface means 42 and 44, respectively, for disposing the optical fibers of one high density set in a predetermined pattern. The surface means 42 and 44 each include an alignment member having optical fiber receiving holes 62 and 64 (as shown in Figs. 4 and 5) at least sufficient in number to receive the optical fibers of one high density set. Moreover, the surface means or alignment members 42 and 44 preferably dispose the optical fibers of the two high density sets 38 and 40, respectively, in parallel planes and the predetermined pattern is defined by the optical fiber receiving holes 62 and 64, respectively, in the alignment members 42 and 44.

Referring to Fig. 3, the connector 20 also preferably includes means 66 associated with at least one of the connector members 24 for biasing the terminating means 36 forwardly therein. The connector member 24 then includes stop means 68 to limit forward movement of the terminating means 36 caused by the biasing means 66 which is preferably a spring with the stop means 68 preferably being a retaining ring. With this construction, the connector member 24 preferably includes a ring receiving groove 70 for the retaining ring 68 outwardly of the terminating means 36 and a spring supporting surface 72 for the spring 66 rearwardly of the terminating means 36.

It will be appreciated by referring to Fig. 1 that the securing means 46 preferably includes a first coupling member 74 associated with one of the connector members 22 and a second coupling member 76 associated with the other of the connector members 24. The first coupling member 74 is engageable with the second coupling member 76 to secure the connector shells 48 and 50 together. Moreover, the securing means 46 optionally advantageously includes means 80 for limiting engagement of the first coupling member 74 with the second coupling member 76 and the limiting means 80 thereby optionally comprises means for controlling separation of the optical fibers of the two high density sets 38 and 40.

Referring again to Figs. 2 and 3, the connector members 22 and 24 preferably include means 82 for orienting the pair of connector members such that the optical fibers of the two high density sets 38 and 40 are in optical alignment when the connector members are secured together with the forward, mating ends 30 and 32 thereof adjacent. In a preferred embodiment, the orienting means 82 includes at least two pins 84 associated with the terminating means 36 of one of the connector members 24 and a corresponding number of pin receiving openings 86 associated with the terminating means 34 of the other of the connector members 22.

In a somewhat more specific sense, the connector 20 includes means 88 and 90 associated with the connector shells 48 and

50 rearwardly of the surface means 42 and 44 for providing stress relief for the optical fibers of one high density set (such as 38 and 40). The stress relief means 88 and 90 preferably include a potting compound associated with each of the connector shells 48 and 50. A potting compound suitably cooperates with each of the connector shells 48 and 50 and preferably includes an elastic compound (such as 88′ and 90′ associated with the rear ends 26 and 28, respectively, thereof and a rigid resin 88″ and 90″ forward of the elastic compound 88′ and 90′, respectively. The stress relief means 88 and 90 can also be utilized to secure the components together in sealed relationship within the connector members 22 and 24. As will be appreciated from Fig. 1, the elastic compound 88′ cooperates with the rear end 26 of the connector member 22 and the elastic compound 90′ cooperates with the rear end 28 of the connector member 24 and, more particularly, with the retaining nut 92 to captivate the components within the connector members 22 and 24, respectively.

Referring still again to Figs. 2 and 3, the terminating means 34 and 36 include alignment plates 42 and 44 and back plates 94 and 96. With alignment plates 42 and 44 comprising the surface means and the back plates 94 and 96 being disposed rearwardly of the alignment plates 42 and 44 to provide support therefor. The back plates 94 and 96 include enlarged openings 98 and 100 (see Figs. 6 and 7) at least coextensive with the corresponding ones of the optical fiber receiving holes 62 and 64 illustrated in Figs. 4 and 5, respectively. Moreover, the optical fibers of one high density set (such as 38 or 40) pass through the enlarged opening 98 or 100 of the back plate 94 or 96 to the corresponding one of the alignment plates 42 and 44, which are secured to the back plates 94 and 96 with the optical fibers, in turn, being secured to the alignment plates.

As will be appreciated, the alignment plate 44 and back plate 96 of one of the connector shells 50 include at least two pin receiving bores 102 with the pins 84 being secured therein and the alignment plate 42 and back plate 94 of the other of the connector shells 48 include a corresponding number of pin receiving openings 86. Preferably, the pin receiving openings 86 include an alignment hole 86′ and an alignment slot 86″ in the alignment plate 42 and back plate 94 of the connector shell 48 with the alignment hole 86′ and the alignment slot 86″ being adapted to receive the pins 84 for orientated and aligned interengagement of the connector shells 48 and 50.

Referring specifically to Fig. 3, the connector shell 50 can include therein a rigid insert 104. The rigid insert 104 is preferrably secured within the connector shell 50 against rearward movement (as shown in Fig. 1). The rigid insert 104 still further preferably has a circumferential groove 106 defining the spring supporting surface 72 (as shown in Fig. 3). The rigid insert 104 is further preferably spaced rearwardly of the backplate 96 with the optical fibers 40 being free to flex in the region between the backplate 96 and the rigid insert 104 (as shown in Figs. 1 and 3). The rigid insert 104 still further preferably includes a pair of slots 108 and 110 to cooperate with the pins 84 for keying the terminating means 36 to the connector shell 50 in a manner permitting relative axial movement (as shown in Fig. 3). The rigid insert 104 also includes a circumferential groove 112 surrounding opening 114 for receiving a resilient sealing grommet or O-ring 58. With the optical fibers of each high density set 38 and 40 being disposed in fiber optic cable 116 and 118 having outer jackets 120 and 122, respectively, the opening 114 in the rigid insert 104 is of sufficient diameter along at least a portion of its length to receive the outer jacket 122 of the fiber optic cable 118 and the grommet or O-ring 58 cooperates with the outer jacket 122 of the fiber optic cable 118 to form a seal.

As best shown in Fig. 3, the connector 20 includes spacer means 124 associated with at least one of the alignment plates 44. The spacer means 124 cooperates with the biasing means or spring 66 to permit controlled separation of the two high density sets 38 and 40 of optical fibers. The terminating means 34 and 36 are preferably located so as to be in contact with the spacer means 124 when the connector shells 48 and 50 are secured together. The spacer means 124 includes a planar sheet secured to one of the alignment plates 44 and having an opening therethrough (not shown) at least coextensive with the optical fiber receiving holes (such as 64). In the alternative, the planar sheet 124 can be a transparent film separator in which case no opening is required in the area of the optical fiber receiving holes.

Referring to Fig. 2, the connector 20 can include means 128 for supporting at least one of the backplates 94. The supporting means 128 is preferably a back plate support member disposed rearwardly of the backplate 94. It will be appreciated that the backplate support member 128 illustrated in Fig. 2 is a generally cylindrical member just adapted to fit within the opening 52 in the connector shell housing the rigid resin 88″. The back plate support member 128 preferably includes a pair of diametrically opposed holes 130 directly in line with a pair of diametrically opposed holes 132 in the connector shell 48 with this construction, the backplate support member 128 can be secured within the connector shell 48 by means of pins 134.

Referring to Figs. 1A and 3A, an alternative

embodiment to the connector member 24 of Figs. 1 and 3 is fully illustrated. The connector member 24′ is entirely identical to the connector member 24 with one important difference. It will be appreciated that the biasing means or spring 66 of Figs. 1 and 3 has been eliminated in Figs. 1A and 3A in favor of a rigid construction. The connector member 24′ therefore includes a somewhat different shaped rigid insert 104′ in the alternative embodiment. More particularly, the rigid insert 104′ is disposed between an internal shoulder 136′ in the connector shell 50′ and the back plate 96′.

As will be appreciated, the back plate 96′ and the rigid insert 104′ are maintained in the connector shell 50′ by means of the retaining ring 68′. The back plate 96′ and the rigid insert 104′ are sized and shaped so as to fit snugly together in the connector shell 50′ against the internal shoulder 136′. It will be appreciated in contrast that the back plate 96 and the rigid insert 104 of the embodiment illustrated in Figs. 1 and 3 are spaced with the rigid insert 104 in abutment with the internal shoulder 136 in the connector shell 50. The rigid insert 104′ is in abutment with the back plate 96′ to provide rigidity. Accordingly, the connector member 24′ provides a distinct alternative to the connector member 24 employing the same basic techniques for high density applications.

Other details of the embodiment of Figs. 1A and 3A are generally the same as the embodiment of Figs. 1 and 3 with minor exceptions. One exception is the shape of the rigid insert 104′ which includes a major diameter opening 138 and a minor diameter opening 140. The major diameter opening and the minor diameter opening are filled with rigid potting resin to secure the set of optical fibers 40′ for a substantial distance rearwardly of the back plate 96′. Another exception is the location at which the outer jacket 122′ is trimmed from the set of optical fibers 40′ rearwardly of the rigid insert 104′. With this construction, the fiber optic cable 118′ is fully secured within the rigid potting resin rather than in the rigid insert 104′.

Referring again to Figs. 2 and 3, the enlarged openings 98 and 100 are shown filled with epoxy at 142 and 144. This secures the sets of optical fibers 38 and 40 within the back plates 94 and 96. It will be appreciated that the alternative shown in Figs. 1A and 3A also includes an enlarged opening 100′ filled with epoxy at 144′ in the back plate 96′, similarly to secure the set of optical fibers 40′ within the back plate 96′. This provides support for the set of optical fibers 40′ at a point immediately rearward of the alignment member 44′. Of course, the epoxy at 142 and 144 in Figs. 2 and 3 provide support for the sets of optical fibers immediately rearwardly of the alignment members 42 and 44.

As indicated, the sets of optical fibers 38 and 40 are secured within the back plates 94 and 96 with epoxy at 142 and 144. This provides support for the optical fibers within the enlarged bores 98 and 100 in the back plates 94 and 96 and the epoxy provides stress relief for the optical fibers. Moreover, the optical fibers in each of the sets 38 and 40 are secured to the respective alignment members or plates 42 and 44 within the optical fiber receiving holes 62 and 64 by means of epoxy.

Referring to Figs. 8 through 10, an alternative embodiment of terminating means is illustrated. The terminating means 146 and 148 include blocks having front faces 150 and 152 defining the surface means. The blocks 146 and 148 include rear portions or faces 154 and 156 and have bores 158 and 160 extending substantially therethrough from the rear faces 154 and 156 toward the front faces 150 and 152. The blocks 146 and 148 further have precision-formed optical fiber receiving holes 162 and 164 (see Fig. 10) in the front faces 150 and 152 in communication with the bores 158 and 160. Moreover, the bores 158 and 160 may include large diameter portions 158′ and 160′ and intermediate diameter portions 158″ and 160″ leading very nearly to the front faces 150 and 152 in which the precision formed optical fiber receiving holes 162 and 164 are made.

Referring to Figs. 9 and 11, means 166 for orienting connector shells is illustrated. The orienting means 166, which is an alternative to the pins 84 and pin receiving openings 86 illustrated in Figs. 2 and 3, can include a lip 168 on one of the terminating means 148 and a lip receiving groove 170 on the other of the terminating means 146. With this construction, the optical fibers of the two high density sets 38 and 40 are in optical alignment when the lip 168 is disposed in the lip receiving groove 170 and the lip 168 and the lip receiving groove 170 can be dimensioned so as to create a gap 172 between the terminating means 146 and 148 to control separation between the optical fibers of the two high density sets 38 and 40.

Referring to Fig. 12, an alternative means of controlling separation of the optical fibers of two high density sets 38 and 40 is illustrated in enlarged detail. This may be substituted for the lip 168 and lip receiving groove 170 arrangement in Fig. 11. It simply includes utilizing a transparent film 174 between the terminating means 146 and 148. This does not, however, provide means for aligning the precision formed optical fiber receiving holes 162 and 164 in the front faces 150 and 152 of the blocks 146 and 148. Accordingly, other means such as those previously discussed could be utilized to accomplish this objective.

Referring one again to Fig. 1, the securing

means 46 preferably includes an internally threaded coupling ring 74 associated with one of the connector shells 48 and an externally threaded surface 76 associated with the other of the connector shells 50. The internally threaded coupling ring 74 is suitably threadingly engageable with the externally threaded surface 76. It will be appreciated that the securing means 46 may further include means for limiting threaded engagement of the internally threaded coupling ring 74 and the externally threaded surface 76. The limiting means 80 comprises means for controlling separation of the optical fibers of the two high density sets 38 and 40. More particularly, the limiting means can optionally comprise proper dimensioning of the forward ends of the connector members 22 and 24 so that the surface 176 of the connector member 24 will engage the surface 178 of the connector member 22 to control separation of the alignment members or plates 42 and 44.

Referring to Fig. 13, the optical fibers of each of the sets 38 and 40 can suitably be terminated in a splice box 180. The splice box 180 includes openings 182 at each end thereof for receiving the optical fibers of a fiber optic cable. It will also be appreciated that the splice box 180 includes tubular extensions 184 through which the optical fibers pass into the splice box 180 for fusion splicing. The tubular extensions 184 cooperate with crimp rings 186 to crimp the outer jacket of the fiber optic cable so as to provide strain relief. With these features of construction, the splice box makes it possible to easily fusion splice optical fibers in a fashion protecting the splice joint.

More particularly, the splice box 180 permits factory termination of the most critical components. It will be appreciated that the fiber optic connector 20 can be fully assembled with fiber optic cables 116 and 118 terminated in the connector members 22 and 24. The splice boxes 180 can be applied to the ends of the fiber optic cables 116 and 118 remote from the connector members 22 and 24 to link the fiber optic cables 116 and 118 to much longer runs of fiber optic cable depending upon the requirement of any particular application. It will be appreciated that this permits maximum quality control in the highly critical assembly and termination of high density sets of optical fibers. Accordingly, the splice box adds a measure of versatility to the fiber optic connectors of the present invention.

Referring to Figs. 4 and 5, the predetermined pattern is defined by at least one row of optical fiber receiving holes 62 and 64. The invention is particularly advantageous, however, for predetermined patterns defined by a plurality of rows and columns of optical fiber receiving holes 62 and 64 as illustrated in Figs. 14 and 15 where eight rows and eight columns have been illustrated purely for purposes of illustration since the exact number of rows and columns may be varied depending upon the needs of a particular application. Preferably, the surface means 42 and 44 include perforated metal alignment plates having the rows and columns of optical fiber receiving holes therein.

In the method of manufacturing a fiber optic connector for optically interconnecting two high density sets of optical fibers, the steps of optical fibers, the steps are the following. First, a pair of connector members each having a rear end and a forward, mating end are provided. Second, a terminating member for association with the forward, mating end of each of the connector members is provided. Third, optical fiber receiving holes are placed in each of the terminating members in a predetermined pattern. Fourth, one of the terminating members is secured in the forward, mating end of each of the connector members. Fifth, the optical fibers of one high density set are secured in the optical fiber receiving holes in each of the terminating members. Preferably, the terminating members are metal and the optical fiber receiving holes are placed by means of metal etching.

With the fiber optic connector for high density applications of the present invention, it is possible to provide a fiber packing density capable of being expanded to hundreds of channels within the internal configuration of standard hardware fittings. The loss at the connector interface and the maximum cross-talk between channels is extremely low. Means of splicing pig-tailed connector assemblies into the cable runs is available as is means of potting the fibers into standard hardware fittings. The loss at the connector interface can be further reduced by optical anti-reflection coatings of the factory terminated interfaces. While threaded couplings have been illustrated, it is, of course, fully contemplated that other couplings such as bayonet lock hardware can be utilized with this invention.

With respect to the connector interface, the alignment members or plates are highly effective. These plates are suitably very thin precision stainless steel with the fiber array holes, the pin alignment holes and the slots being precisely fabricated. The connector members can suitably be supplied with one meter length pig-tails for fusion splicing into a cable harness. By so doing, factory fabrication is possible to locate the most critical assembly and inspection operations at the location of maximum talent leaving only the fusion splice operation for field personnel. With the alternative embodiment illustrated in Figs. 8 through 12, the production of a mating face can be accomplished according to the following steps. First, a photolithographic mask of a fiber optic array is prepared. Second a plate of

a basic material (for example, copper) is machined. Third, the plate is drilled with guide holes in the back of the plate very nearly to the front of the plate. Fourth, the front of the plate is then lapped to a mirror finish and the photolithographic mask is used to deposit an absorptive material upon it. Fifth, a laser drill is focused upon the darkened areas of the absorptive material to burn through the remainder of the plate from the front surface until the holes drilled from the front and rear surfaces are in communication. While it is expected that the holes drilled from the front surface and from the rear surface will not share mutual axes, the misalignment will not be great enough to preclude the fibers being inserted from the rear to be guided through the front of the plate.

With the various concepts and techniques set forth herein, a fiber optic connector for high density applications and a method of manufacturing fiber optic connectors are provided. The present invention includes features of construction will suited for optically interconnecting two high density sets of optical fibers using a surprisingly advantageous combination and arrangement of components and alternatives thereto which make it possible to increase the capacity of prior fiber optic connectors by several orders of magnitude. Accordingly, it will be appreciated that the goal of providing a fiber optic connector for high density applications approaching the loss and cross-talk characteristics which are essential in fiber optics has been accomplished.

While in the foregoing specification a detailed description of the inventive concepts has been set forth for purposes of illustration, the details herein given may be varied by those skilled in the art without departing from the spirit and scope of the invention set forth in the appended claims.

CLAIMS

1. A fiber optic connector for optically interconnecting two high density sets of optical fibers, comprising: a pair of connector members each having a rear end and a forward, mating end; means associated with said forward, mating end of each of said connector members for terminating one high density set of said optical fibers, each of said terminating means including means for disposing said optical fibers of one high density set in a predetermined pattern; and means for securing said connector members together with said forward, mating ends thereof adjacent so that said optical fibers of said two high density sets are in optical alignment.

2. The fiber optic connector as claimed in Claim 1 wherein said connector members each include a connector shell having an opening extending completely therethrough from said rear end to said forward, mating end, said opening being sized and shaped to accommodate one high density set of said optical fibers.

3. The fiber optic connector as claimed in Claim 2 wherein said connector shells each include means associated therewith for providing a sealed connector, said sealing means including means associated with said rear ends and means associated with said forward mating ends when said connector members are secured together.

4. The fiber optic connector as claimed in Claim 3 wherein said sealing means includes a resilient O-ring associated rearwardly of said forward, mating end of at least one of said connector shells and a resilient O-ring associated with said forward, mating ends when said connector shells are secured together, said resilient O-rings each being disposed in a circumferentially extending groove.

5. The fiber optic connector as claimed in Claim 2, further including means associated with each of said connector shells rearwardly of said surface means for providing stress relief for said optical fibers of one high density set.

6. The fiber optic connector of Claim 5 wherein said stress relief means includes a potting compound associated with each of said connector shells.

7. The fiber optic connector of Claim 6 wherein said potting compound is disposed within each of said connector shells and includes an elastic compound adjacent said rear ends thereof and a rigid resin forward of said elastic compound.

8. The fiber optic connector of Claim 2 wherein said disposing means include surface means for disposing said optical fibers of said two high density sets in parallel planes.

9. The fiber optic connector of Claim 8 wherein said surface means each include an alignment plate having optical fiber receiving holes therein at least sufficient in number to receive said optical fibers of one high density set, said predetermined pattern being defined by said optical fiber receiving holes in said surface means.

10. The fiber optic connector of Claim 9 wherein said terminating means further include back plates, said back plates being disposed rearwardly of said alignment plates to provide support therefor, said alignment plates being secured to said back plates.

11. The fiber optic connector as claimed in Claim 10 wherein said backplates each include enlarged openings at least coextensive with the corresponding ones of said optical fiber receiving holes, said optical fibers of each high density set passing through said enlarged openings of each of said back-plates to the corresponding one of said alignment plates, said optical fibers being secured to said alignment plates.

12. The fiber optic connector as claimed in Claim 11 wherein said optical fibers are

supported within said enlarged openings in said backplates with epoxy, said epoxy providing stress relief for said optical fibers, said optical fibers being secured to said alignment plates with epoxy.

13. The fiber optic connector of Claim 10 wherein said terminating means includes means for orienting said pair of connector shells such that said optical fibers of said two high density sets are in optical alignment when said connector shells are secured together with said forward, mating ends thereof adjacent.

14. The fiber optic connector of Claim 13 wherein said orienting means includes at least two pins associated with said terminating means of one of said connector shells and a corresponding number of pin receiving openings associated with said terminating means of the other of said connector shells.

15. The fiber optic connector of Claim 14 wherein said alignment plate and backplate of one of said connector shells includes said two pin receiving bores, said pins being secured in said pin receiving bores and wherein said alignment plate and backplate of the other of said connector shells include said corresponding number of pin receiving openings.

16. The fiber optic connector of Claim 15 wherein said pin receiving openings include an alignment hole and an alignment slot in said alignment plate and said backplate of the other of said connector shells, said alignment hole and alignment slot being adapted to receive said pins for oriented and aligned interengagement of said connector shells.

17. The fiber optic connector of Claim 13, wherein said orienting means includes a lip on one of said terminating means and a lip receiving groove on the other of said terminating means, said optical fibers of said two high density sets being in optical alignment when said lip is disposed in said lip receiving groove.

18. The fiber optic connector of Claim 10 including means associated with at least one of said connector shells for biasing said terminating means forwardly therein, said connector shell including stop means to limit forward movement of said terminating means caused by said biasing means.

19. The fiber optic connector of Claim 18 Wherein said biasing means is a spring and said stop means is a retaining ring, said connector shell including a ring receiving groove for said retaining ring outwardly of said alignment plate and a spring supporting surface rearwardly of said backplate.

20. The fiber optic connector of Claim 19, including a rigid insert in said at least one connector shell, said rigid insert being secured within said connector shell against rearward movement, said rigid insert further having a circumferential groove defining said spring supporting surface.

21. The fiber optic connector of Claim 20 wherein said rigid insert is spaced rearwardly of said backplate, said optical fibers being free to flex in the region between said backplate and said rigid insert.

22. The fiber optic connector of Claim 20 wherein said rigid insert includes a pair of slots and wherein said backplate and alignment plate include a pair of pins, said pins keying said terminating means to said connector shell in a manner permitting relative axial movement.

23. The fiber optic connector of Claim 20, wherein said optical fibers of each high density set are disposed in a fiber optic cable having an outer jacket, said rigid insert having an opening extending completely therethrough, said opening in said rigid insert being of sufficient diameter along at least a portion of its length to receive said outer jacket of said fiber optic cable.

24. The fiber optic connector of Claim 23 wherein said rigid insert includes a circumferential groove surrounding said opening for receiving a resilient sealing grommet, said grommet cooperating with said outer jacket of said fiber optic cable to form a seal.

25. The fiber optic connector of Claim 18 including spacer means associated with at least one of said alignment plates, said spacer means cooperating with said biasing means to permit controlled separation of said two high density sets of optical fibers, said terminating means being located so as to be in contact with said spacer means when said connector shells are secured together.

26. The fiber optic connector of Claim 25 wherein said spacer means includes a planar sheet secured to one of said alignment plates, said planar sheet having an opening therethrough at least coextensive with said optical fiber receiving holes.

27. The fiber optic connector of Claim 10 including means for supporting said backplates, said supporting means including a backplate support member disposed rearwardly of said backplate in each of said connector shells, said backplate support members being secured to the respective ones of said connector shells.

28. The fiber optic connector of Claim 9 wherein said predetermined pattern is defined by at least one row of optical fiber receiving holes.

29. The fiber optic connector of Claim 28 wherein said predetermined pattern is defined by a plurality of rows and columns of said optical fibers receiving holes.

30. The fiber optic connector of Claim 29 wherein said alignment plate is metallic in said rows and columns.

31. The fiber optic connector of Claim 1 wherein said terminating means each include a block having a front face defining said surface means and a rear face, said blocks

each having bores extending substantially therethrough from said rear face toward said front face, said blocks also each having precision formed optical fiber receiving holes in said front face in communication with said bores.

32. The fiber optic connector of Claim 1 wherein said securing means includes a first coupling member associated with one of said connector members and a second coupling member associated with the other of said connector members, said first coupling member being engageable with said second coupling member to secure said connector shells together.

33. The fiber optic connector of Claim 32 wherein said securing means further includes means for limiting engagement of said first coupling member with said second coupling member, said limiting means comprising means for controlling separation of said optical fibers of said two high density sets.

34. The fiber optic connector of Claim 32 wherein one of said coupling members is an internally threaded coupling ring and the other one of said coupling members is an externally threaded surface on the other of said connector members said internally threaded coupling ring being threadingly engageable with said externally threaded surface.

35. The fiber optic connector of Claim 34 wherein said securing means further includes means for limiting threading engagement of said internally threaded coupling ring and said externally threaded surface, said limiting means comprising means for controlling separation of said optical fibers of said two high density sets.

36. The fiber optic connector of Claim 1 wherein said optical fibers of each high density set are terminated in a splice box.

37. A method of manufacturing a fiber optic connector for optically interconnecting two high density sets of optical fibers, comprising the steps of: providing a pair of connector members each having a rear end and a forward, mating end; providing a terminating member for association with said forward, mating end of each of said connector members; placing optical fiber receiving holes in each of said terminating members in a predetermined pattern; securing one of said terminating members in said forward, mating end of each of said connector members; and securing said optical fibers of one high density set in said optical fiber receiving holes in each of said terminating members.

38. The method of Claim 38 wherein said terminating members are metal and said optical fiber receiving holes are placed by means of metal etching.

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